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Satellite Low Rate Voice Demonstration Test Plan

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December 1988

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16. Abstract

This test plan describes the design of the demonstration of a low data rate voice Codec communications link via satellite. The demonstration will include the use of 4.8 kbps voice Codec equipment interfaced with a mobile satellite (MSAT) communications terminal installed in the Federal Aviation Administration's (FAA's) B-727 (N-40) aircraft and similar equipment at the COMSAT ground earth station in Southbury, Connecticut. This configuration, used in conjunction with INMARSAT satellite capability, completes an aircraft-to-satellite-to-ground facility circuit that provides a communications quality voice link between the pilot and the ground. In addition to a demonstration, techniques will be developed for evaluating voice Codecs for air traffic control (ATC) applications. Controllers from the FAA will be used in the evaluation. A Codec Test Bed Facility will be developed to conduct stress testing in a laboratory controlled environment. This project will allow critical evaluation of digital voice satellite communications technology in a simulated ATC environment.

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EXECUTIVE SUMMARY

This plan describes the design of the demonstration of a low data rate voice Codec communications link via satellite. The demonstration will include the use of 4.8 kbps voice Codec equipment interfaced with a mobile satellite (MSAT) communications terminal installed in the Federal Aviation Administration's B-727 (N-40) aircraft and similar equipment at the COMSAT ground earth station in Southbury, Connecticut. This configuration, used in conjunction with INMARSAT satellite capability, completes an aircraft-to-satellite-to-ground facility circuit that provides a communications quality voice link between the pilot and the ground. In addition to a demonstration, techniques will be developed for evaluating voice Codecs for air traffic control (ATC) applications. Controllers from the FAA will be used in the evaluation. A Codec Test Bed Facility will be developed to conduct stress testing in a laboratory controlled environment. This project will allow critical evaluation of digital voice satellite communications technology in a simulated ATC environment.

INTRODUCTION

OBJECTIVE.

This test plan describes a demonstration of low data rate digitized voice communications via a satellite link. The intent is to demonstrate and evaluate the potential of low rate voice Codec technology for Federal Aviation Administration (FAA) air traffic control (ATC) applications, particularly in oceanic sectors, remote areas, and offshore locations where very high frequency (VHF) line of sight radio services are not available.

OVERVIEW.

A two-way satellite voice communications link will be established between the FAA's B-727 (N-40) test aircraft and the COMSAT ground earth station (GES) in Southbury, Connecticut. The aircraft, flying in oceanic airspace, will be equipped with a mobile satellite L-band communications terminal called MSAT. The MSAT terminal, provided by NASA/Jet Propulsion Laboratory (JPL), will contain 4.8 kbps voice Codec equipment that will permit the cockpit crew to communicate using the technology of digitized speech transmission and reception. A similar Codec will be installed at the satellite ground earth station operated by COMSAT where testing will be conducted (see figure 1). The FAA may set up an additional link using a leased line between the GES and a remote location for demonstration purposes.

Prior to the demonstration flights, a test bed facility will be established for test and evaluation of other Codecs. Development of Codec evaluation techniques for future ATC applications will be of primary interest. First, Codecs will undergo subjective listening evaluations by air traffic controllers. This will be an iterative process. Later, the higher scoring Codecs will be subject to comprehensive, controlled tests in the Codec Test Bed Facility.

BACKGROUND.

Oceanic ATC at New York and Oakland are presently being served by limited range VHF radio and high frequency (HF) radio for extended distances. HF radio has often proved to be unreliable due to propagation outages and atmospheric noise conditions. Satellite communications overcome these limitations and provide global coverage over the heavily traveled air routes of the Atlantic and Pacific Oceans. This project brings together several proven communication technologies that may improve the controller's ability to reliably communicate with aircraft operating in oceanic regions or in offshore areas, thereby improving safety and operational efficiency.

JPL has developed a MSAT terminal which has undergone field trials using a pseudo-satellite mounted on a tower. Through an agreement between NASA/JPL and the FAA, a joint cooperative effort has been defined in which JPL will provide MSAT communications equipment and engineering support for the evaluation/demonstration.

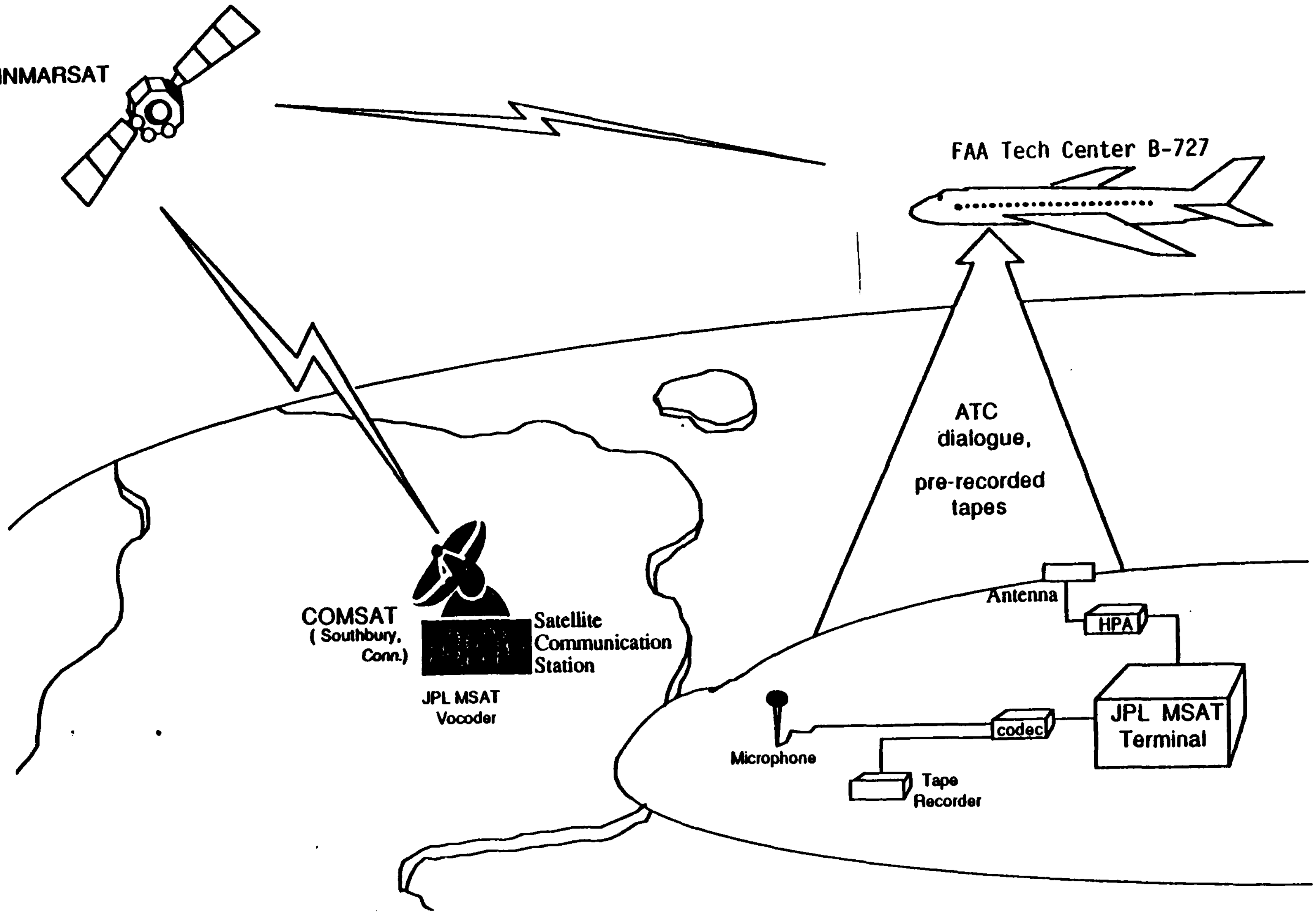

FIGURE 1. SATELLITE LOW RATE VOICE DEMONSTRATION

RELATED DOCUMENTATION.

1. Airlines Electronic Engineering Committee, British Telecom Codec Test Specification, AEEC letter 88-085/SAT - 84, May 23, 1988.

2. Aeronautical Radio Inc., Project Paper 741: Aviation Satellite Communications System, Draft 2A (and supplements), October 30, 1987.

3. National Aeronautics and Space Administration, Goddard Space Flight Center Report, Voice Coding and Intelligibility Testing for a Satellite Based Air Traffic Control System, April 1971.

4. Quackenbush, Barnwell, and Clements, Objectives of Speech Quality, Prentice Hall, 1988.

5. Dessouky, Jet Propulsion Laboratory, Definition of Joint JPL/FAA Experiment, Draft, July 12, 1988.

EQUIPMENT

The equipment required for this demonstration will be supplied by the FAA and JPL. JPL will supply a 4.8 kbps Codec developed under contract to the University of California at Santa Barbara. The FAA will supply the aircraft to serve as the mobile test bed and may supply other Codecs (the number of Codecs is undetermined pending the results of an industry survey and extensive preflight testing). JPL will provide satellite communication avionics and ground equipment. JPL will also arrange for the satellite services of INMARSAT and for ground earth station use from COMSAT.

VOICE CODECS.

The JPL 4.8 kbps Codec will be used in the demonstration. If time permits, other Codecs will be used in the demonstration. Codecs will be used in pairs, one Codec installed in the aircraft for the cockpit crew and a corresponding Codec installed at the COMSAT ground earth station. Noise cancelling handsets will be used to offset aircraft background noise.

CODEC TEST BED FACILITY.

A test facility will be set up in order to objectively evaluate various voice Codecs in a controlled environment. The lab set-up (see figure 2) will simulate a satellite communications channel which includes cockpit/controller background noise. The channel will allow packetized voice transmission of live, store and forward, and canned messages.

SATELLITE COMMUNICATIONS.

JPL's MSAT terminal will be installed in the B-727 aircraft. The terminal contains an L-band receiver and transmitter, modems, and a 4.8 Codec. In order to communicate with the satellite at the assigned L-band frequency (1.6 GHz), additional equipment is required. A high power amplifier (HPA) and a satellite communication antenna have also been procured for use in the demonstrations.

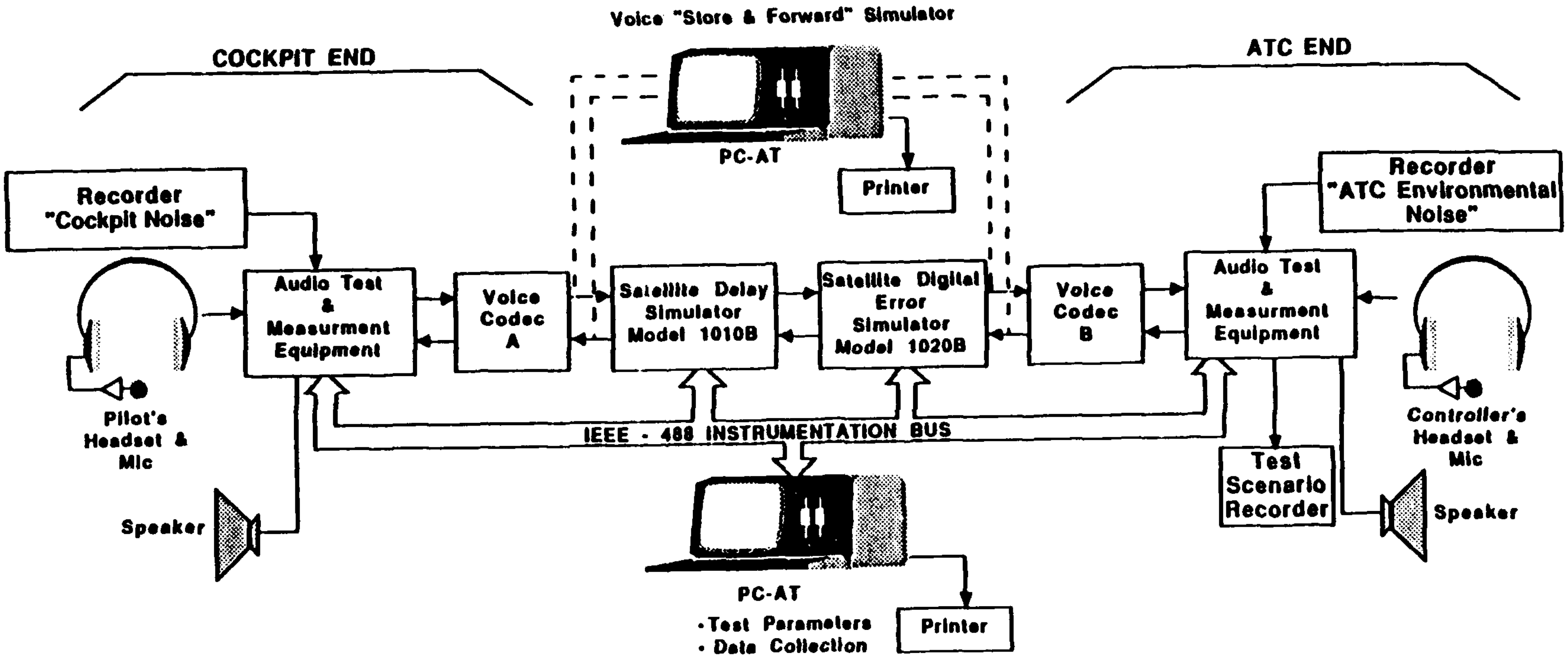

FIGURE 2. BLOCK DIAGRAM OF CODEC TEST BED FACILITY

Antenna. JPL has fabricated two high gain dual helical spiral antennas to be installed on the port and starboard side of the aircraft. A specially designed window mounted satellite communications antenna may be installed on either side of the aircraft by the FAA, if time permits. During flight operations the appropriate antenna would be used to stay within view of the satellite.

Satellite. An INMARSAT communications satellite located 26 degrees west of the zero meridian over the equator will be used to support the demonstration.

DATA COLLECTION AND ANALYSIS

Tests will be performed during the various stages of this project. Codecs will first undergo subjective listening evaluation by air traffic controllers; then they will be subjected to rigorous testing in a laboratory setting. Flight tests will be contingent upon successful ground tests. For a more detailed account of testing, see Related Documentation, item 5.

CONTROLLER TESTS.

At the inception of this project, an industry survey was conducted to determine the availability and performance characteristics of 4.8 and 2.4 kbps Codecs. The manufacturers of Codecs were identified and asked to participate in a pre-qualification exercise in which they were to receive and process through their Codecs a cassette test tape consisting of approximately 1 hour of prerecorded audio material. They were instructed to record the results and submit their tapes to the FAA for a subjective listening evaluation. The Codecs will be ranked based upon the results of a modified mean opinion scoring (MOS) test conducted with New York Air Route Traffic Control Center (ARTCC) controllers as listening participants. Additional testing may be conducted to refine the Codec evaluation technique. An independent agency may be used for further subjective listening evaluations.

CODEC TEST BED FACILITY TESTS.

The highest ranking Codecs will be selected for more rigorous testing in the Codec Test Bed Facility where they will be evaluated on performance in a satellite link and background noise environment. Evaluation of speech quality will require determining intelligibility and speech quality vs. bit error rate (BER). High speed data acquisition and analysis software will be used to measure the A/D and D/A sample and hold spectrum, bit-by-bit waveform performance, and spectral power efficiency vs. time.

PREFLIGHT TESTS.

Initial tests of the equipment will take place on the ground. A fixed station, consisting of a low gain antenna, modem, Codec, and a terminal processor with a laptop computer, will be used to communicate with the MSAT equipment installed on the aircraft via an L-band translator mounted in the FAA hangar (building 301).

Full voice and data links will be tested in this set-up before proceeding to ground demonstrations using the satellite.

Preliminary data collection will be conducted for later analysis. Ground checkout will include HPA power output, receiver performance, e.g., measurement of signal-to-noise ratio (SNR), threshold, BER performance, and system noise figure. Antenna performance parameters such as gain/temperature (G/T), radio frequency (RF) transmission line, and diplexer losses may be determined. The aircraft will be rotated to vary the SNR ratio. The effects of various SNR ratios on parameters such as acquisition and recovery will be determined. Packet Error Rate (PER), which can be derived from BER, will be tested for both long (continuous) and short (bursty) transmissions to evaluate the data link. For voice testing, speech quality and BER performance will be evaluated. BER vs. SNR will be plotted. Voice data will be recorded on the aircraft and at the GES for later analysis.

FLIGHT TESTS.

During the demonstration flights, data will be collected for post-flight analysis. Flight tests similar to those of preflight testing of voice and data links will be performed. Evaluation of the Codecs will include analysis of intelligibility and speech quality vs. BER. Adequacy of the link power budget will be determined. The effects of multipath and Doppler shift will also be examined.

FLIGHT TEST/DEMONSTRATION

The demonstrations will take place in March 1989. Approximately two or three flights will be conducted. The flights will take place late night between 12:00 a.m. and 4:00 a.m. in order to obtain the needed flightpath and available satellite time. The flightpath of the demonstration (see figure 3) has been chosen such that the aircraft maintains a constant elevation angle with the satellite and minimizes Doppler effects. Test personnel will be stationed on the aircraft and at the COMSAT GES. Full cooperation of the New York ARTCC controllers is expected.

FLIGHT TEST SCENARIO.

1. Set-up Equipment.

   a. Atlantic City, N.J.:

      (1) Turn on and test JPL MSAT Equipment on N-40 (B-727).

      (2) Attempt to establish Digital voice contact between N-40 and COMSAT GES.

      (3) Establish VHF or HF radio contact between N-40 and COMSAT GES.

      (4) Prepare for takeoff.

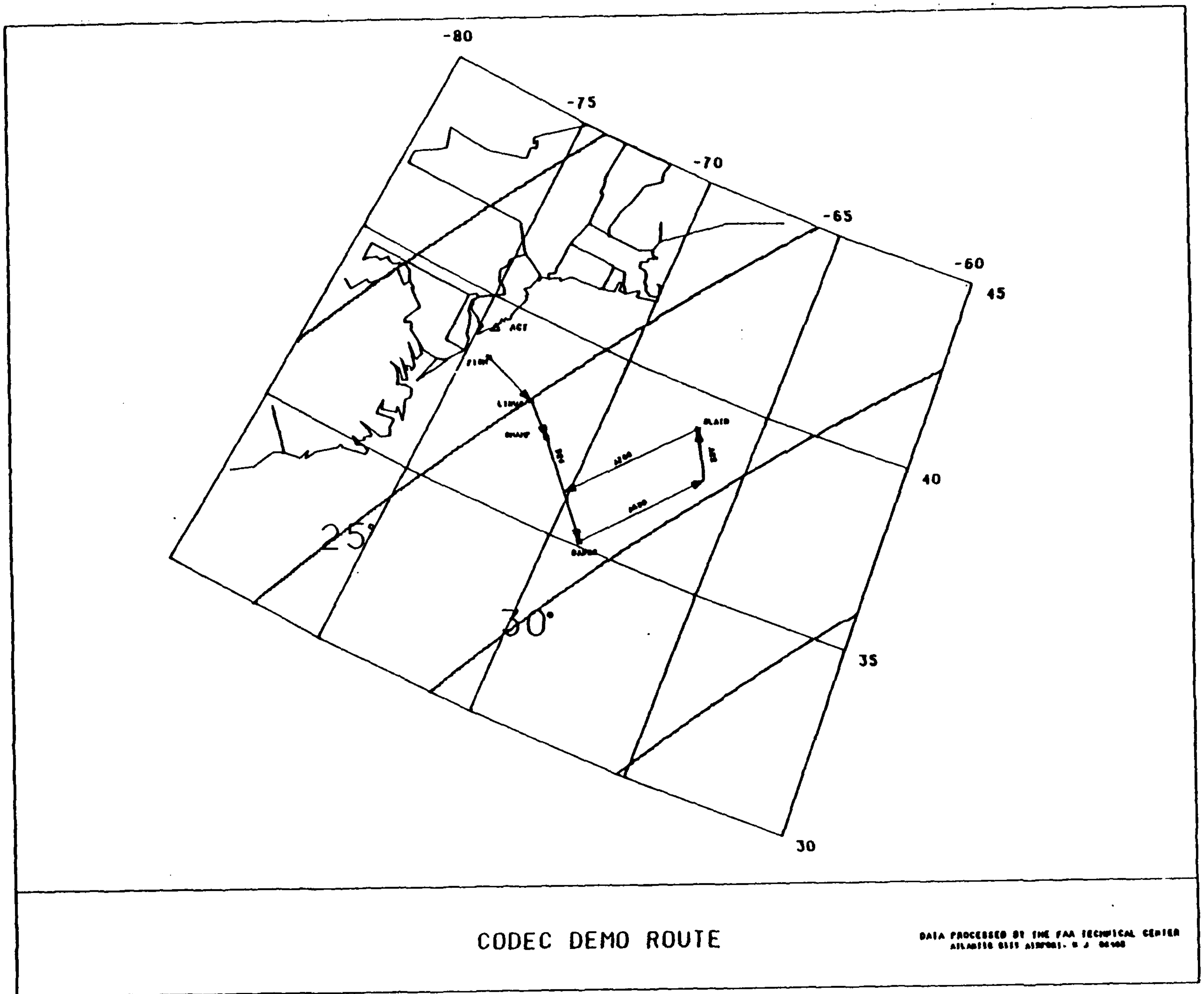

FIGURE 3. FLIGHT TEST ROUTE

b. Southbury, Conn.:

(1) Turn on JPL MSAT equipment.

(2) Establish radio contact with N-40.

2. Demo Scenario.

a. Depart ACY and pick up flight route B24 east. Continue on B24 to A700. Take A700 north to Waypoint SLATN. Adjust flight speed to require approximately 1/2 hour flight time to SLATN.

b. Flight test personnel should establish digital voice link with the GES.

c. Simulate normal pilot to ATC communication using digital voice equipment. For example, give position report and ATC flight clearance exchanges. Simulate a request for a change in altitude. Conversation should continue approximately 15 minutes.

d. Play test tape into digital voice equipment for approximately 15 minutes.

e. Arrive at Waypoint SLATN, turn east on flight route A22. Discontinue digital voice communication and move MSAT antenna to other side of N-40 for communication on next leg of flight.

f. Arrive at intersection of flight route A22 and A699. Turn south on A699. Flight crew reestablishes digital voice link with GES.

g. Continue south on A699 to Waypoint DANER. Adjust flight speed to require approximately 1/2 hour flight time to get to DANER. After digital voice link has been reestablished, continue playing test tape into equipment for approximately 15 minutes.

h. Simulate pilot to ATC conversation as in 3 above.

i. Arrive at Waypoint DANER, turn west on flight route B24. Continue on B24 to ACY.

j. Conclude Demonstration.

(1) Land N-40.

(2) Shut down equipment.

AREAS OF RESPONSIBILITY

ASA-210:

Provide broad strategic management.

Program scheduling and funding.

ACD-330:

Provision of FAA B-727 as flight test bed.

Aircraft available for MSAT terminal and associated equipment installation and follow up tests.

All FAA B-727 flight costs.

Experiment Codirection.

Test Plan.

Frequency coordination as may be required.

Documentation of aircraft/payload constraints.

Physical Integration of MSAT terminal and associated equipment into aircraft with JPL technical assistance.

Support for integration and tests.

FAA ground test facilities and sites, as required.

Funding for/provision of aircraft antennas suitable for supporting voice with earth coverage INMARSAT satellites.

Prepare mounting bracket for antennas.

Fabricate aircraft racks to mount MSAT equipment.

Cover cost of shipment of MSAT equipment.

Interface development for accommodation of non-MSAT voice Codecs as a possible add-on to the demonstration.

Provision of non-MSAT voice Codecs, if this option is exercised.

NASA/JPL:

Experiment codirection.

Coordination for test plan.

MSAT terminal and associated equipment for aircraft and satellite ground station installations.

Integration plan, procedures, and direction.

COMSAT/INMARSAT coordination for satellite facilities and ground station access.

Technical support for aircraft and ground station installation of MSAT equipment.

Technical support for A/C and satellite ground station MSAT terminal equipment for experiments.

Configuration of MSAT terminal equipment to work with earth coverage INMARSAT satellites.

Supply antenna for aircraft.

Supply HPA.

SCEDULE

The satellite low rate voice demonstration schedule is provided.

SATELLITE LOW RATE VOICE DEMONSTRATION SCHEDULE